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A Taxonomy of Response Processes

by

Elmo E. Miller

HumRRO Division No. 2

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HUMAN RESOURCES RESEARCH ORGANIZATION

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The Human Resources Research Organization (HumRRO) is a nonprofit corporation established in 1969 to conduct research in the field of training and education. It is a continuation of The George Washington University Human Resources Research Office. HumRRO's general purpose is to improve human performance, particularly in organizational settings, through behavioral and social science research, development, and consultation. HumRRO's mission in work performed under contract with the Department of the Army is to conduct research in the fields of training, motivation, and leadership.

FOREWORD

Basic Research Study 8, Classification of Common Job Elements for Common Training, was undertaken by the Human Resources Research Office in FY 1963. The objective is to study training methods, technqiues, and strategies, and the stimulus, trainee, and response elements involved in the learning process, for the purpose of developing a classification system of training methods in terms of the types of job tasks to which each training method is most usefully applicable. This research project is an outgrowth of an Exploratory Study (ES-6) of the feasibility of developing a classification system for training content.

BR-8 research has been conducted at HumRRO Division No. 2, under the supervision of Dr. Norman Willard, Jr., as Director. Support is provided by the U.S. Army Armor Human Research Unit. COL Charles Brown was Chief of the Unit during the conduct of the work described in this report. The current Director of the Division is Dr. Donald F. Haggard and the Chief of the Unit is LTC John Hutchins.

Three aspects of the training process—stimulus input, trainee factors, and response output—have been studied. This report is a summary of the work completed to date on the response aspect of the problem. Work on the stimulus aspect of the problem has involved research in the learning of both verbal and nonverbal stimuli.

The initial research resulted in a Research Memorandum, The Feasibility of Developing a Task Classification Structure for Ordering Training Principles and Training Content, January 1963. In addition, several journal articles have been published to date, and other reports are in preparation.

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Meredith P. Crawford
President
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Problem

The people who design any training course must decide what training methods to use and, presumably, different training methods are appropriate for different kinds of tasks. For instance, one would suppose that the methods appropriate for training someone to start a tank's engines would differ from the methods appropriate for training someone to control a guided missile (such as the SS-10). The process of determining what training method would be effective might be facilitated by appropriate classifications for training methods and tasks.

This report describes a classification system for distinguishing the various "kinds" of tasks, and also a classification of general training methods (called "training strategies") that might be used. The kinds of tasks considered are restricted to those commonly known as "perceptual-motor" tasks. The report also discusses, in a preliminary way, how each training strategy is most appropriate for certain kinds of tasks, and inappropriate for others.

Approach

A pool of response distinctions was collected, partly from the professional literature and partly from analysis of task examples. A list of training strategies was also gleaned from the same general sources. Each of these lists was structured, with some aid from a technique called "connotative clustering." Certain response elements were defined to clarify relationships between training strategies and types of tasks. Finally, the various kinds of tasks and training strategies were arranged in a matrix for systematic comparison of each kind of task with each kind of training strategy.

Results

Training strategies (or training methods) are of two general kinds: (a) the operational conditions of practice (including how the task environment is represented, how the person is told what to do, special information on how well he has done, how the task is divided into practice sessions, and how incentives are managed), and (b) diagnosis of the behavioral process (figuring out what is wrong with a student's performance, and what might be done to correct the process). In order to consider how the training strategies are related to each kind of task, task elements are delineated in terms of cue functions, image or mediational functions, and movement tendency.

Motor tasks are of four general kinds:

(1) **Reactive—adjustive** (common name, "tracking" or "adjusting"). Common example: steering a car.

(2) **Reactive—selection from a set of responses** (no common name). Some common examples: typing, sending Morse code, playing piano from music.

(3) **Developmental—procedural** (common name, "procedures"). Some common examples: flight procedures in an aircraft, starting procedures for a tank.

(4) **Developmental—skilled performance** (common terms are unfortunately vague here). Some common examples: batting a ball, hurdling an obstacle.

In the reactive categories, the student is to respond to a series of cues, each of which determines what response is required. With *reactive-adjustive* tasks, there is an underlying continuum—usually spatial—for the stimulus and response dimensions, and the response directly alters the stimulus dimension. The task is to reduce a discrepancy in the stimulus dimension to zero. With *reactive-choice* tasks, the responses made are chosen from a set of responses appropriate in that general task context; each response is called out by its symbolic equivalent in the environment.

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With developmental tasks, the character of the required performance changes with time during any particular repetition (i.e., the task performance develops from a beginning to an end). *Developmental–procedural* tasks involve performing a series of steps in fixed order. The response criterion is *what* is performed, not how well it is performed. *Developmental–skilled performance* tasks involve attaining an increasing degree of skill in controlling an ever-changing process.

Within each general kind of task, certain distinctions are noted that are likely to be important in determining the kind of training used. Such distinctions seem rather specific to each kind of task, indicating perhaps that the defining characteristics of the general classes are somewhat fundamental.

Conclusions

(1) The classification system appears to be workable and promising. It identifies various characteristics that seem relevant in the selection of training methods for particular training programs. Preliminary consideration of the categories suggests that the best training methods for one type of task are not the best methods for another type of task.

(2) The classification system appears sufficiently promising to warrant further development. Such development would include three kinds of effort:

Formal and theoretical development. More examples of tasks and training methods should be considered. The whole classification system (including the kinds of tasks, the kinds of training strategies, and the relations between them) could be refined. The classification should be related to other theoretic systems as they are developed.

Programatic experimentation. Evaluation and refinement of the taxonomy would also involve various kinds of experimentation, including (a) having people sort various task examples into the categories, to test for reliability of sorting; (b) having people rate the applicability of various training strategies to certain task examples, to assess consistency of applying the strategies to tasks; and (c) conducting experiments that would demonstrate whether certain training strategies are especially effective for certain kinds of tasks.

Practical application. The usefulness of the system in practical application is a final test of the system. Practical application may also lead to further refinement of the classification by indicating which aspects are most useful and by clarifying the shortcomings that appear. Practical application may also lead other researchers to use some of the features in their theoretic systems.

A Taxonomy of
Response Processes

Chapter 1

PROBLEM AND APPROACH

THE PROBLEM

The purpose of the task taxonomy described in this report is to sort tasks in such a way that a different set of training strategies (or training methods, or training techniques) is applicable to each category of task. Such a sorting of tasks should be an aid in the design of training programs. This paper is a report of progress in developing a system for classifying the response aspect of task performance. A tentative taxonomy is presented, followed by a discussion of how the task distinctions are related to various training strategies.

The scope of this paper is restricted to classification of responses, or response processes. Such tasks generally are included under the topics, "motor tasks," "perceptual-motor tasks," "perceptual-motor skill learning," "response learning," or "skilled movements." Admittedly, the area of response processes has vague boundaries, but these limits may become sharper through definition and explication of the categories. When there is doubt whether response processes are involved, they have been included to avoid gaps that might cause difficulty when the taxonomy is integrated with other systems.

The crux of concern has been the differential applicability of the various training strategies to various kinds of tasks. One would have such differential applicability if a particular training strategy were appropriate for task A but not task B, while a different strategy were appropriate for task B but not for task A. This differential applicability would change the design of training by narrowing the range of alternative strategies to be considered for any particular task.

The training strategies (or training methods) which are to be applied are themselves somewhat vague, so they must be clarified in order to develop a taxonomy of responses. Also, in order to relate the training strategies to the various kinds of tasks, a common terminology will be needed for both strategies and tasks, so it is necessary to define explicitly various aspects of "responses."

The initial problem of developing a useful taxonomy of responses, then, involves clarifying the whole system of terminology for talking about training, including the various aspects of responses and the training strategies to be applied, as well as the kinds of tasks to be learned. Such systematic terminology should help to clarify the whole process of training and training management.

If the terminology developed is to be useful in the foreseeable future, new technical terms should be kept to a minimum so that the system can be readily adapted to everyday usage. As a matter of fact, the common task constructs, such as "tracking," "procedures," "adjusting," and "skilled performance," are likely to involve considerable wisdom, however unsystematic. It is hoped that the value implicit in these common terms can be exploited through a process of explication, increasing the usefulness of the system.

This process of explication, being a matter of language, is likely to yield the logical distinctions among tasks. These logical distinctions will naturally

form the major task categories, since the defining characteristics of such task categories may, by their very nature, exclude the necessary conditions for applying many of the training strategies. Within the major logical categories, empirical relationships may be discovered or relationships noted in past research may gain in clarity and precision.

BACKGROUND

Laboratory Research and Taxonomy

Most task taxonomies (including the present effort) employ the kinds of operational distinctions characteristic of applied research in training and education. Such operations are not easily derived from most theoretical or laboratory experiments, few of which compare the efficiency of various training methods or strategies. Instead, laboratory studies typically involve experimental comparisons among various kinds of material to be learned, or among various kinds of people; in training situations, the kinds of material and learners are fixed, rather than a matter of choice.

Ideally, one would like to see experiments in which various training strategies are applied to various tasks, and compared for effectiveness; at the least one would want to compare various strategies as applied to the same task. Actually, theoretical experiments rarely compare training strategies for effectiveness. If one wishes to make any inferences concerning the best training method for each kind of task, one must consider the trends in long series of learning experiments.

The two areas of research—applied and theoretical learning—appear to be treated as if they were completely separate topics in the literature. The "estrangement" between them is critical, because it determines how theoretical studies relate to this taxonomy, which is based on concepts developed in applied research.

In the area of teaching motor skills, West (1, 2) attempts to relate general learning principles to the research on teaching typewriting. His effort is salutory; however, it is apparent that if the general learning principles are to be applied unambiguously, they must be supplemented by extensive specific experimentation on typing. For instance, he recommends against using blank keys or key caps (1), on the basis of his review of experimental work, and considers this rule an instance of applying the principles of reinforcement and contiguity. One might readily recommend the opposite on the basis of transfer, unless one knew that sight typing would, in fact, "disappear of its own accord."

There is a certain vagueness about applying general learning principles to particular skills; even worse, experiments on teaching particular skills seem to have little or no effect upon general learning theory. For instance, in a recent review of motor skills research, Bilodeau and Bilodeau (3) do not refer to experiments on teaching typing, or any other practical skill (with the dubious exception of a few studies using simulators, apparently available as experiment apparatus because they were either obsolete or invalid). This is no criticism of the reviewers, but rather a significant fact about the current disjunction of learning and training research.

Theorists in learning try to vary conditions according to basic underlying factors; they are little concerned with what can be varied readily in practical situations. They have tended toward standard apparatus and standard tasks, to control task differences. Underwood (4, p. 74) has noted the tendency to record

only certain response measures. Also, learning theorists have tended to simplify the learning situation to its essentials according to their theories and methods, whereas the crux of a training situation often seems to be its unique pattern of interdependent and/or interlaced performance requirements. The more complex task structures take a longer time to learn than is generally available in the experimental hour.

The tendency to oversimplify the task shows signs of waning; Fitts (5), in reviewing skill learning, considered the hierarchical task structure of extreme importance for theory. But in the past, the learning theorists have tended to use experimental paradigms that are inappropriate for revealing task differences, or for determining the most efficient teaching methods. Therefore, for the present purposes, one can expect little aid from particular laboratory experiments until there are sufficient data (from many experiments) to indicate constructs that will have pervasive validity.

Of the learning authorities who contributed to Melton's recent book, Categories of Human Learning (6), none proposed a systematic task taxonomy, either for distinguishing basic learning factors or for determining training methods. However, many systematic and apparently useful distinctions were drawn.

Insofar as researchers tend to concentrate effort within one type of task, they may fail to note distinctions among tasks. This is especially likely where the distinctions are matters of logic (i.e., where a defining characteristic of a principle is excluded), because the non-applicability usually is so obvious that stating it seems silly. Although such distinctions may appear trivial in detail, their implications may be commonly disregarded in the larger context of total job performance which usually includes a conglomeration of skills. Such logical distinctions would most naturally underlie the major category divisions; the less absolute, often quantitative, empirical distinctions would form the subdivisions.

Types of Task Taxonomies

There are various purposes for which one might formulate a task taxonomy:

(1) Predicting the skill level of various trainees on particular tasks, such as those in selection tests, factor analytic studies, or simple correlation studies.

(2) Designing equipment so that particular tasks may be performed more efficiently, including the allocation of tasks among jobs, and designing the man-machine interface.

(3) Determining which training strategies, or educational techniques, are most appropriate for particular tasks, as in the effort of Bloom and his associates (7) or in the present project.

(4) Discerning which underlying learning processes are the most important ones in the acquisition of particular tasks.

There is no reason to suppose that one task taxonomy is most appropriate for all these purposes. In fact, different purposes tend to direct attention to different aspects of the subject. For example, when one is allocating duties to various stations, concurrency of functions is a more basic consideration than the skill needed, but the same emphasis is not true for selection research. Similarly, a taxonomy that distinguishes basic learning processes may not be entirely suitable for determining effective training methods.

Melton (6, p. 332) makes essentially this point in discussing the evolution of task taxonomy from primitive operational distinctions. He contends that a sophisticated operational task classification will continue to be needed for the analytical and empirical activities of psychology even if theory should eventually

yield a completely different set of categories based upon distinctions among processes or constructs. One might argue further that a sophisticated operational task classification is especially likely to be helpful in relating the tasks to training strategies, or to educational techniques, because such strategies (techniques) are also defined in terms of operations.

Review of Task Taxonomies

There are several other recent classification projects which have the same purpose as this report, as well as several which have different purposes.

Cotterman (8, 9) has suggested the development of a task taxonomy to help relate knowledge and theories of learning to training situations, by forming task categories that distinguish the applicability of the various principles. He felt that it was wisest to begin with abstract characteristics of traditional, simple laboratory experiments—including certain stimulus characteristics, certain response characteristics, and several consistencies in relational properties of stimuli and responses (8, 9, 10, 11). The characteristics he chose to note differ markedly from those which others have used for classification, with the possible exception of Stolurow. This fact indicates the diversity of things which one might choose to observe. Cotterman claims no compelling reason why these particular distinctions are most apt to lead to a useful taxonomy, but he specifies the criteria by which they might be verified (8).

Stolurow (12, 13) uses many of the same distinctions as Cotterman, as Haggard (14, p. 38) has observed. But Stolurow based his choice upon functions involved in a man's performance as a part of a larger system (12). Like Cotterman, he is attempting to facilitate application of learning principles by defining their limits of generality. His approach to classification is admittedly intuitive (13, p. 3), but is aided by a general knowledge of the experimental learning literature.

In his later work (13, p. 79) Stolurow considered the trainee as a system, and distinguished tasks on both input and output for the following dimensions: number and sequence, limits (i.e., tolerance limits or class boundaries), meaningfulness (including both association and order), and the qualitative relations between input and output (i.e., whether input and output belong to the same class). He reviews parts of the experimental literature to show that his task dimensions tend to correlate with the kind of experimental results obtained, at least to a limited degree (13, pp. 36-77). However, when expert judges (PhD psychologists) were asked to code and decode tasks according to the categories, there was little apparent agreement (13, pp. 145-151). Such lack of agreement is common in newly developed classification or coding systems, and perhaps his suggested refinement of the categories, and better instructions for the judges, may improve reliability of coding.

Haggard (14) has written a review of taxonomies, and, although he does not purport to present a system, he makes several points that are useful in constructing a taxonomy.

While Cotterman and Stolurow were concerned almost exclusively with application of learning principles, Haggard is concerned with applying training technology as well as learning principles, and with anything that may be used to systematize the development of training programs. Haggard recognizes the desirability of a generalized conceptual system for learning phenomena, but also suggests a classification system of psychological phenomena "to deal only with the level of generality which is the primary concern of the training psychologist" (14, p. 56). Haggard also discusses general approaches to taxonomies as they might be applied to developing a task taxonomy.

The present author (15, 16) designed a general task classification to aid in applying knowledge about learning and training. The older Miller system was designed to cover all learning tasks, and its categories have no exact correspondence with the system to be described in this paper. The earlier system used conventional terms for its major divisions: (a) perceptual-motor skill learning, (b) discovery or understanding, (c) perceptual learning, and (d) memorizing. The criteria for the categories were to be applied successively, and these criteria were directly related to the kinds of operations one might use for training, so that the categories necessarily pertained to training operations. The effort was also concerned with analyzing the disparate activities found in job situations ("conglomerate learning requirements"), and with handling the special problems of classifying highly similar tasks on which subjects learn how to learn ("composite learning activities").

Of all current efforts, the rationale of Bloom and his associates (7) is perhaps closest to that of the present paper. He states (p. 6) that

> . . . first importance should be given to educational considerations
> Insofar as possible, the boundaries between categories should be
> closely related to the distinctions teachers make in planning
> curricula or in choosing learning situations.[1]

Such planning and choosing are similar to selecting a training strategy. Bloom inten : his taxonomy to be a rather concise model for the analysis of educational outcomes in the cognitive area. Thus he tries to aid in communication and analysis of educational objectives, and in choosing a plan, and he does not restrict himself to the application of verified, well-formulated principles of learning. This taxonomy was developed from an extensive set of examples.

Bloom and his associates restricted themselves to the cognitive domain (7, p. 7). Another (later) volume, by Krathwohl, Bloom, and Masia, is devoted to the affective domain (17). The "manipulative or motor-skill area" (p. 7) they call "the third domain," but they do not consider it important enough for their purposes to warrant development.

Gagne (18, 19 20, 21, 22, 23, 24, 25) and R.B. Miller (26, 27, 28, 29, 30, 31) have devised systems for talking about human skills in their discussions of task analysis, and their systems can be considered a rudimentary taxonomy. Recently, R.B. Miller (32) stated that he considered his work not so much as a taxonomy based on scientific constructs, but as a tool for talking about the variables which can be manipulated practically; in this, he appears to have succeeded if one is to judge by the wide use of his concepts in task analysis and similar endeavors.

R.B. Miller (31, p. 201) distinguishes situational elements as a basis for a taxonomy; these include (a) indicator, (b) action, (c) control, and (d) an indication of response adequacy. Similarly, the present paper will distinguish "task elements" as a basis for distinguishing training strategies and task categories. Gagne (24) has distinguished several kinds of learning: response differentiation, associations, multiple discriminations (identification), behavior chains, class concepts, principles, and strategies. In another recent source (25), he distinguishes eight varieties of learning: signal learning, stimulus-response learning, chaining, verbal-associate learning, multiple discrimination, concept learning, principle learning, and problem solving.

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Some task taxonomies have been derived from factor analyses. Guilford (33) views the intellect as having three dimensions, each having several divisions:

I. Operations	II. Products	III. Contents
Evaluation	Units	Figural
Convergent Production	Classes	Symbolic
Divergent Production	Relations	Semantic
Memory	Systems	Behavioral
Cognition	Transformations	
	Implications	

These three dimensions form a matrix, in which each cell represents a factor.

Guilford's factorial categories are similar in some respects to Bloom's categories. This partial correspondence in the cognitive area might be useful to the present classification effort, because the same kinds of relationships may hold between factor analyses of perceptual-motor performance (e.g. Fleishman, 34) and the present effort to describe response processes.

Guilford's Operations dimension is strikingly similar to some of Bloom's major categories:

Bloom, et al.	Guilford
Knowledge	Memory
Comprehension } Application	Cognition
Analysis } Synthesis	Divergent thinking Convergent thinking
Evaluation	Evaluation

The Products dimension seems to correspond at several points with Bloom's subcategories, but here the similarity seems somewhat less direct. For example, the Units X Memory cells (Guilford) apparently correspond with Bloom's "Knowledge of specifics."

There are undoubtedly striking differences also, and it would be unwise to stretch the comparisons too far. For example, in Bloom's taxonomy the behaviors are conceived as hierarchical (7, pp. 17-19); anyone interested in amalgamating these two cognitive taxonomies might consult Jones' monograph (35) relating correlational analyses to hierarchical structures of tasks.

Guilford's third dimension, Contents, has no apparent correlates in Bloom's system. This is to be expected, because Bloom's classification is designed to be content-free, applicable across the various subject matters.

When one considers the factor analyses of motor skills (34, 36, 37, 38, 39) in an attempt to infer some characteristics of motor tasks, the findings do not correspond neatly to the dimensions of Operations, Products, and Contents, although some aspects of these findings may be considered according to such dimensions. Perhaps a greater degree of dimensionality will appear as the field develops, or as researchers develop a more nearly adequate nomenclature for motor skills. One certainly cannot get a dimensional structure of factors until many factors—the more the be. r—have been identified and described. Also, the tasks used must require complex abilities if complex factors are to appear from the analysis. Of the factors described by Fleishman and Hempel (34), Factor I (Discrimination Reaction Time) and Factor II (Simple Reaction Time) might be considered as Operations, but on a very simple or molecular level. The other factors seem closest to the Contents area. Guilford (36) tries to

structure the factors, with one dimension for the part of the body involved, and another dimension for the type of ability involved.

Fleishman's later work reveals increasingly rich and complex structure (38, 39), and he reports 11 psychomotor factors (including control precision, multi-limb coordination, response orientation, reaction time, speed-of-arm movement, rate control, manual dexterity, finger dexterity, arm-hand steadiness, wrist-finger speed, aiming), and nine physical proficiency factors (extent flexibility, dynamic flexibility, static strength, dynamic strength, trunk strength, gross body coordination, gross body equilibrium, and stamina).

APPROACH

Much of the approach stems rather directly from the analysis of the problem, as it was stated at the beginning of this paper. Thus, devising a taxonomy of tasks really consisted of three projects: (a) the taxonomy of tasks itself, (b) an explicit taxonomy of the training strategies to be applied to the tasks, and (c) definition of certain constructs which are needed in order to relate the two taxonomies. These efforts were so interdependent that, in fact, all three were developed together.

The professional literature was consulted, especially the writing of those psychologists analyzing the training process. The work of Gagne and R.B. Miller in particular influenced the work, both in the kinds of distinctions made and in several of the actual distinctions. Of the taxonomists, Bloom and his associates (7) followed a rationale and approach close to the one used for the classification reported in this paper. However, the circumstances have induced a marked change in emphasis. The extensive formal list of examples which they had was not available for this research, nor was the amount of professional labor for considering such examples. Instead, task examples were considered somewhat informally; greater weight was given to actual task distinctions commonly noted, and to the training strategies that might be applied.

The work of Fleishman and his associates on the factor analyses of motor skills should relate eventually to the taxonomy reported here, but the gross organization of their factors does not yet seem to relate directly. One consideration is that many of their factors concerned content, and a content-free taxonomy was needed here for purposes of applying training strategies. Similarly, when Bloom's taxonomy was compared with that of Guilford and his associates, there was a lack of correspondence on the Contents dimension.

A large pool of response distinctions was gathered from various sources; for example, several response distinctions may be inferred from the kinds of standard research apparatus listed by Bilodeau and Bilodeau (3, p. 245). At this stage, there is no attempt to exclude response distinctions for any reason. These distinctions are then organized into a very preliminary taxonomy, on the basis of relations which appear important for this kind of endeavor. The distinctions which appear not to be useful are retained in a pool for reconsideration later; their organization is likely to suggest refinements of definition. Much of the experimental literature (e.g., the kinds of apparatus listed by Bilodeau and Bilodeau) tends to emphasize tracking skills far beyond their importance for the general range of practical response processes; also, some of the distinctions made do not appear to relate to other useful distinctions, so they are tentatively disregarded.

Many of the response distinctions are simply recollections from several years of professional experience in task analysis and training analysis, and the

sources have long since been forgotten. For the reader who may not be familiar with such analyses, or for the sophisticated reader who may wish to consider examples of analyses performed for this report, the Appendix presents analyses of a diverse sample of common tasks familiar to nearly everyone. The task examples are riding a bicycle, driving a nail, tying a square knot, an aircraft flight procedure, typing, associating the burners on a kitchen range, and "trimming" an aircraft. These tasks and analyses are cited as specific illustrations, and should not be construed as supporting evidence for the taxonomy. The validity of the taxonomy does not rest upon the validity of these analyses, but only upon the validity of the kinds of distinctions drawn, as refined by the process of explication used in the study.

A variety of training strategies were also collected from the literature and from professional experience, and formulated explicitly. They were organized on the basis of apparent similarities.

The meaningful organization of both the training strategies and the response distinctions is admittedly an intuitive process, but the work was aided considerably by a technique that might be called "connotative clustering —a method for organizing complex fields of study. The first step is to collect a long list of distinctions that might apply, without attention to order. The second step is to obtain a large sheet of paper, and to write the first term in the middle of the page. The second term is written some distance from the first, the closeness depending upon how closely they seem to be related. Then the third term is added in relation to the first two, forming some sort of triangle, and so on, through the list. The more closely the terms appear to be related the nearer they are placed. As the work proceeds, meaningful clusters appear, which can be defined and formally related to nearby clusters. In the process, some terms or clusters of terms that have been placed apart may appear related; such oversights can be corrected by drawing a line between such points.

Connotative clustering is especially useful when terms and relations among terms are complex and highly abstract. The effectiveness of the method depends upon the fact that often one can sense relatedness without being able to define the relation explicitly, and that one can better define a category by using a whole cluster of examples than with a single example.

As the task distinctions and training strategies were organized, it became apparent that certain aspects of responses needed better definition, in order to relate the two systems. Finally, each training strategy and each task distinction were considered together, in order to discern any restrictions on applicability of the strategy, either logical (as a matter of the definitions) or empirical (on the basis of experimental findings). In principle, this is a matrix approach, with task distinctions arrayed along one margin and the training strategies along the other (12). In practice, the approach can be simplified somewhat by noticing some relations that are apparent before the matrix is constructed, thereby organizing and reducing the comparisons.

As the project proceeded, there was modification and development of each of the three aspects—the definition of terms, the training strategies, and the task taxonomy. As one aspect is developed and organized, it is likely to indicate useful order for organizing the other aspects of the project.

THE CONCEPT OF "RESPONSE"

ACHIEVEMENT LANGUAGE

The term <u>response</u> has long been a source of difficulty for psychologists. Some of the issues are particularly critical for developing training strategies, and for developing a taxonomy of tasks, so these issues are discussed in this chapter.

This report will use an <u>achievement</u> language to specify responses. An achievement language, generally employed by such cognitive theorists as Tolman, is one which MacCorquodale and Meehl (40, p. 230) distinguish as requiring "an explicit reference to the stimulus side in its characterization of the response."[1] Certain general assumptions will be made about the response process which might be considered implicit in the achievement language: (a) A response is primarily a matter of the image which it is to bring about, and it is stored in memory, organized, and retrieved by this image; (b) this image is compared with the present stimulus field to yield an initial movement tendency; and (c) there is a repetitive feedback process in which the image is compared with the current stimulus field to yield successive movements. In cases where there is insufficient time for the feedback process, there will be a "ballistic" movement. It is assumed that this conception of the response process is appropriate, not only for molar phenomena but also at any molecular level with which this report will be concerned.

The foregoing conception of a <u>response</u> process allows one to make distinctions that would not be apparent in the overt, muscular movements. A sharp distinction is made here between "scanning" and the "nystagmus" of a disoriented person, although the two phenomena have highly similar patterns of muscular jerks. Scanning is an ocular adjustment performed in order to produce an intended visual field, whereas the nystagmus of a disoriented person is a response triggered by the interoceptive component of the ocular adjustment system, in conflict with the visual stimulus field.

The status of images is another problem in defining a response. Eliciting images is an extremely important part of training for many response-loaded processes. Many examples are given by Sheffield (41, 42). Yet one would hesitate to call eliciting an image a <u>response</u>, for traditionally a response has been a muscular movement or glandular secretion. In any case, the recall of an image is something a person does, or can be directed to do, and serves the function of a mediating event; that is, once aroused, it serves as a stimulus and thereby changes the characteristics of responses that follow it, as does any mediating activity. Many commonly used training strategies involve directed recall of images as mediating events (e.g., discussion of driving a nail, Appendix).

Another problem is that response is a class concept. When one says that the trainee made a correct response on a trial, one means that the event fell

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within a certain range of conditions which define that response. The class nature of the response concept is true for any experiment, but it is especially likely to be a source of confusion in training studies, because there are likely to be discontinuities in the defining characteristics of the subclasses. That is to say, there are likely to be several distinctly different techniques for achieving successful, or correct, responses. In bowling, for example, there are a three-step approach, a four-step approach, and even a five-step approach, and each option has its own pattern of movements; however, each pattern is a perfectly acceptable mode of delivery.

At the broadest, a satisfactory response (or criterion response) may be defined as whatever response produces the subsystem objective, or the individual's goal--whatever "gets the job done." But generally the task involves some indication of the technique, or the variety of techniques, that would be considered acceptable. That is, not only is the product to be achieved specified, but also some restriction is imposed on the process for achieving it. Thus athletic coaches generally put some limits on form early in learning a skill, because certain response patterns are known to be bad practice in the long run, even if they produce a modicum of early success.

The restrictions placed on acceptable technique never completely specify the exact response process. The covert process which achieves the correct response is generally a matter of some ingenuity on the part of either the learner or his coach, and one can never know whether or not a more efficient mnemonic will be discovered the very next day (item 6, Appendix illustrates this).

ANALYSIS INTO SUBTASKS

Most jobs consist of several tasks that differ markedly from each other. Such an assortment of activities has been called "conglomerate learning requirements" (16). No one would expect all activities to fall into a single category, to be treated alike. If one can analyze a job into tasks that fit neatly into categories, then one can greatly simplify the application of the taxonomy. Often some major demarcations are obvious; further divisions are a matter of achieving the purposes of the particular task analysis.

These pragmatic considerations are the crux of defining the level of complexity which is to be implied by the term "task." Obviously, a job such as "truck driver" is too diverse to be called a task, because many different training strategies would have to be used in training. Filling out a particular record form for each trip, however, might be called a task because it can be trained by one approach or set of training strategies. Similarly, the actual driving might be considered a task (excluding maintenance and repair) because it is relatively homogeneous as to training methodology required. There would seem little administrative convenience by grouping into larger activity units, and smaller units would gloss over important characteristics common to different tasks.

However, each task usually can be divided usefully into subtasks for special treatment during training. For instance, the task of filling out a particular form might be divided usefully into subtasks of filling out each item in the form, because many of these items might each be taught most effectively by a particular mnemonic for the particular difficulties students have with that block. The complexity level of a task or a subtask, then, is a relative matter for convenient administration of training, in order to deal with skill units that are reasonably homogeneous with respect to the training methods that are appropriate.

When jobs are analyzed into tasks and subtasks, three kinds of relation-ships commonly appear:

(1) Successive subtasks. Here we are concerned with different phases of a job, if the job seems to change in character during its performance. The separation in time minimizes the risk of overlooking important interactions.

(2) Concurrent, independent subtasks. Here we are dealing with duties which, while they are time-shared, do not depend upon each other and might be done as well by two different people.

(3) Concurrent, inte. related subtasks. Here some aspects of the response in one subtask pertain also to performance on the other subtasks. For instance, the analysis of riding a bicycle (Aprendix) derived three interrelated concurrent subtasks: (a) deciding on the path of travel, (b) leaning to turn, and (c) turning the handlebars to keep balance at the angle of bank (lean). Each component subtask provides some indication of cue and feedback from the environ-ment. For example, a bicycle rider can sense his angle of leaning directly, without having to observe, over time, his rate of turn. The subject has the possibility of using such indications of response adequacy for subtasks in order to perform more efficiently, as compared with performing the "same" task (that is, tracking with the same mathematical relationship between handlebars and the track of the tires along the ground) but without any other visual cues or interoceptive motion cues (this latter would be a pure, abstract double inte-gral tracking task). Experience with such tasks seems to indicate that the extra cues make a critical difference in difficulty, and it certainly should not be assumed that these cues are unimportant to the task structure.

The foregoing example illustrates the importance of considering several task characteristics in addition to the pure mathematical relationship between the control and the track generated. Also, if such analysis into subtasks is valid and useful for training, then each of the subtasks, if phrased properly, should be a meaningful division for people who can ride bicycles. The analy-sis should be helpful in arranging conditions for training bicycle riders.

TRANSFER OF PREVIOUSLY LEARNED SKILLS

When a conglomerate learning requirement is analyzed into tasks and sub-tasks, some students may already have mastered some of the subtasks and will have no need for the training strategies for that kind of task. This point is ap* to complicate the effort of empirically evaluating the effectiveness of various training strategies for particular tasks.

CERTAIN TASK ELEMENTS DEFINED

The common aspects, or functions, involved in overt responses will be used as elements in defining training strategies and task categories, and in considering the relationships between them. These are parts of the process of task performance on the job; the list of functions specifically excludes coaching, directions from the instructor, or any other instructional information that is not present on the job.

The functions include the cues for the required responses, the images that are to be used to mediate the required overt responses, and the required overt movement. The functions are outlined and defined in the following paragraphs.

A. Cue

1. Variety of cue. The varieties of cues are defined by their functions in relation to the required overt responses. Although such functional dimensions are the basic considera-tion for cues, it seems simpler to talk about kinds of cues than about functions or basic dimensions, because of the kinds of interrelations among cue dimensions.

The functional dimensions for distinguishing cues are (a) the chronology of the cue, in reference to the response; (b) the physical basis of the cue, or the values which the cue might assume; and (c) the number of response choices included in the appropriate response set, from which the cue delineates the required response(s).

The chronology of the cue concerns whether or not the cue determines the timing (the correct instant) for the response. The physical basis of the cue (or the values of the function) is determined in order to distinguish among three subclasses of cue functions: (a) a continuum, (b) a conventional sign whose denotation has been established by previous learning, or (c) a new sign, whose meaning is established in that task context. The number of response choices in the appropriate response set refers primarily to whether there is only one response choice, when the cue merely indicates when it is to be performed.

For present purposes, the following kinds of cues are distinguished.

  a. Timing cue. Cues of this kind signal only the moment at which a response is appropriate. Thus, they do *not* indicate a choice among responses. One might wish to distinguish two kinds of timing cues:

    (1) Triggering cue. which is a cue to begin an action (e.g., in the flight procedures, Appendix, "at 100 knots full throttle").

    (2) Terminal cue, which is a cue to cease action (e.g., the snap of a toggle switch when pressure is sufficient to trip it). In some cases, the terminal cue may correspond to the goal image, as defined below.

  b. Selection cue. The cue informs the trainee what action to perform.

    (1) Specifying (prompting) stimulus. Each cue is a conventional sign for the required response (so there is a one-to-one correspondence between cue and response choice). There must be more than one response choice in the response set—for example, typing. In typing, the specifying stimulus is a job cue, an integral part of the task.

    (2) Significative cue. Each cue value must be interpreted by the trainee, in the task context, as to the action required. For example, in riding a bicycle, he must decide in what direction, and how far, to turn the handlebars in order to maintain balance. The cue function may be either a continuum or a sign established in the task context. The cue cannot be a conventional sign, standing for the required response, because its significance must be established in the task context. The significative cue may sometimes serve the function of a timing cue. There must be a choice between two or more responses, corresponding to the interpretation of stimulus states.

2. Intercue dependencies. Intercue dependencies are the overlap, or correlated information in different cue functions.

  a. Interdependency of cues between subtasks. In this situation the response in one subtask produces, or affects, the cues for another subtask. For example, in flying an aircraft, one can hold an attitude more easily and with greater accuracy if the trim controls are properly adjusted (see Appendix). Trimming is a subtask in flying, and it changes the whole pattern of pressures required, so as to make the desired attitude attainable with zero pressure on stick and pedals, and any change in attitude requires pressure from that reference condition.

  b. Interpendency within a cue function, across time. This is represented by the relation between what is presented and what has been presented before.

    (1) Performance feedback is the stimulus resulting from one's previous responses. In tracking, this would be quantitative (the amount of error). Tracking is quantitative because there is an implied reference system, including target, or cursor, and distances which indicate accuracy. In other skills, feedback might be qualitative. For example, in learning to pronounce foreign words the sound of a word uttered by oneself is considered qualitative, because there is no simple presumed set of dimensions by which the differences can be described readily. Of course, the differences could be dimensionalized and quantified, but the appropriate dimensions are not explicit and obvious.

    (2) Autocorrelation is the amount of correlation with a previous cycle of the stimulus function, irrespective of the trainee's performance (e.g., the cue function on cycles of the pursuit rotor are perfectly correlated).

B. Guidance images: Images serving various functions as mediating events.
 1. Goal images. A goal image is the subject's impression of the situation which his response
    is intended to produce, and which is used to adjust the actual situation.
    a. Final goal image. The desired end result of a series of responses is the final goal image.
       For example, there is a joke about a sculptor who is asked how he carves an elephant.
       He replies, "I get a large block of stone and chip away everything that doesn't look like
       an elephant."
    b. Subgoal image. The image of the situation at significant points in the process is the
       subgoal image. This includes the desired motion. Often the choice of a time sample
       for this image is critical, because one particular point in the process is especially apt
       to induce errors. For example, in tying a square knot, the status just after the halfway
       point is likely to be critical, because many learners err at this point by placing one rope
       end on the wrong side of the other end, thereby producing a "granny" knot.
 2. Encoding structure. The encoding structure is an image of the process, not immediately
    apparent in the task situation—generally, an analogy with some structure learned in the
    past. For example, in the range example in Appendix, the U and upside-down U are ways
    of imposing order on the pairing of burners and controls, without regard to any intrinsic
    validity of the image induced.
C. Movement tendency: This is the volition to effect a change in the environment, by muscular
   pressure or movement. In its purest form, this aspect is seen in a ballistic movement, or
   pressure. More commonly, however, the movement tendency is repeatedly (continuously?)
   interacting with performance feedback, to determine the next movement tendency.

Chapter 3

TRAINING STRATEGIES

This chapter presents a classification of strategies that might be used to train someone. The formulation of these strategies is closely related to the classification of tasks, because the task taxonomy is intended to aid in an appropriate choice of training strategies for any particular task requirements.

The phrase training strategy denotes a specific policy for manipulating the variables available in the training context to induce particular changes in behavior; it means roughly the same as training method or training technique. However, training strategy is not equivalent to a learning principle. It is rather more likely that the useful training strategies will represent a balance between somewhat antagonistic learning processes, involving several learning constructs. For example, prompting (telling the student the answer before he has a chance to guess) is a generally effective training strategy (43, 44, 45, 46, 47, 48), especially if there are occasional test trials (43). It would appear that this part-prompting strategy is a balance between the following more basic learning factors: (a) change in strength of the responses, both correct and incorrect, due to repetition; and (b) effect of test conditions (absence of prompts, forcing unaided recall) upon learning. Of course, these more basic learning factors can be manipulated only indirectly through varying the training strategy.

The main headings in the outline are dimensions of classification, rather than divisions. For this reason, any particular adjustment in a training program is likely represent both a change in the practice environment and a diagnosis of the trainee's learning process. The training strategies are outlined in Table 1 and are discussed in detail in the following paragraphs.

A. Operational Conditions of Practice. This aspect deals with the operations that are performed by an instructor during training, rather than any inferred process that might account for the performance of the trainee.

1. Representation of the Task Environment. This dimension of the strategy refers to how the task environment is simulated during training.

a. Unmodified task environment. The task is represented as realistically, as completely, as is practicable. There may be simplifications, or even additional information presented, as in prompting. But the stimulus and response elements are present, and in the correct relationships.

b. Purposeful modification of task environment.

(1) Stimulus predifferentiation. Generally the stimuli are presented, but the actual overt job responses are not required. The purpose generally is to get the subject to react to the various stimulus states, as such, irrespective of the final overt responses.

(a) Terminology practice. The process involves naming stimulus (cue) states, perhaps with prompting or confirmation.

(b) Progressive narrowing of discrimination. Start by presenting gross differences, or typical cases, and gradually introduce the fine differences. (This technique might be used in combination with terminology drill.)

(c) Demonstrating tolerance limits. For example, show dipstick when the oil level is too low, just barely.

(d) Recalling differences. The student is required to describe the differences in cue states; or in some cases, he may be required to produce the cue differences

Table 1

Training Strategies

Operational Conditions of Practice	Diagnosis of the Behavioral Process
1. Representation of the task environment	1. Promoting intrinsic KR
a. Unmodified task environment	a. Clarifying goal state
b. Purposeful modification of task environment	b. Calling attention to benchmarks (subgoal
(1) Stimulus predifferentiation	images)
(a) Terminology practice	c. Providing supplementary KR
(b) Progressive narrowing of discrimination	2. Fostering conception of underlying process
(c) Demonstrating tolerance limits	3. Establishing a more effective response set
(d) Recalling differences	a. Promoting movement consistency for better
(2) Response differentiation	feedback
(a) Practicing at slower rate	b. Establishing response set which permits
Task-paced tasks	sensing of feedback
Self-paced tasks	4. Inducing set for appropriate response pattern
(b) Reducing force or amplitude required	a. Physically guiding responses
(c) Relaxing qualitative standards for	b. Describing desired modifications of responses
responses	c. Inducing set to avoid common mistakes
2. Analysis into subtasks	d. Instructing on grip or stance
a. Successive phases	5. Inducing cue sensitivity
b. Concurrent subtasks	a. Signaling, during task performance, the
(1) Independent subtasks	moment for a response
(2) Interdependent subtasks	b. Describing situation which is to trigger the
3. Performance requirements information (telling	action
trainee what to do)	6. Encouraging anticipation of the response (reading
a. Size of behavioral unit described	ahead)
b. Contingencies for prompting	
(1) Time in training	
(2) Trainee's past performance	
(3) Properties of responses required	
(4) Speed of response	
(5) Trainee's request for prompt	
c. Completeness of prompts	
(1) Cue (partial)	
(2) Prompt (complete)	
4. Supplementary knowledge of results (KR)	
a. Size of response unit	
(1) KR after each step	
(2) KR after end result	
(a) General KR	
(b) KR specific to a particular step	
b. Form of KR	
(1) Providing comparison	
(2) Giving assessment	
5. Manipulating incentives	
a. Adding incentives	
b. Emphasizing existing incentives	

        (2) Response differentiation. The response exercise is conducted under pro-
gressively more difficult conditions (often called shaping). The stimulus conditions may be
simplified, to provide only enough cue support for effective response practice.
        (a) Practicing slower rate.
            Task-paced tasks. The task pace is progressively increased until the cri-
terion performance is reached. This method implies that the performance is task-paced.
            Self-paced tasks. The acceptable rate of production is progressively increased,
and the subject is encouraged to work faster. This method implies that the performance
is self-paced.

(b) Reducing force or amplitude required. Generally, such a training tactic is used when trainees do not meet the force or amplitude requirements at first. However, on some tasks an instructor might initially require greater force or amplitude early in training, in order to emphasize muscular feedback.

(c) Relaxing qualitative standards for responses. Early in training, a more lenient standard or form of correct response is used than could be justified in the criterion performance. In this category, the correct overt response is a matter of a whole pattern of movement, and to describe the pattern one would need to mention several characteristics. Responses that are unsatisfactory on only one dimension would most likely be corrected by one of the methods mentioned above under speed, pacing, force, or amplitude of response.

2. Analysis Into Subtasks.
a. Successive phases. This dimension merely indicates that most jobs have phases which differ from each other, and that as a matter of convenience (or to emphasize the differences in the phases) they are practiced separately.
b. Concurrent subtasks.
(1) Independent subtasks. The independent nature of such functions may be emphasized by independent practice, and such practice may reduce the risk of overburdening the trainee early in training.
(2) Interdependent subtasks. Learning the dependencies is a part of learning the task in many cases. The dependencies may be analyzed as discussed above, and sometimes practice can be administered separately. For example, in flying an aircraft, accurate stick movements are dependent on using trim tabs to relieve excessive stick pressures. Thus skillful use of trim tabs can be taught first, to simplify the learning of stick movements (49).

3. Performance Requirements Information (Telling the Trainee What to Do). This consists of information to the trainee during practice; it specifies what he must do to meet the criterion performance. The information may be rather complete, as in a full explanation, or a brief symbolic indication of the required response, as in a prompted response. (Without such information, the subject would have to learn by trial and error.) The various divisions distinguish how and when the information is given; it is assumed, at least, that the information is given after the response as knowledge of results, if not sooner.
a. Size of behavioral unit described. This refers to how much task information is given before the corresponding responses are required. Presumably, this is related to the student's memory span. At one extreme, the whole task might be described before any overt responses are performed (as a soldier might read a description of how to disassemble his weapon, clean it, and assemble it, just before attempting to do it). At the other extreme, one might describe such a small step in the task that a trainee could hardly forget what to do (e.g., press a particular button on his weapon and slide out the magazine.) A moderately fine task division might give him as many steps as he could remember, but no more.
b. Contingencies for prompting. Whether a trainee gets prompted before his corresponding responses might depend on several things:
(1) Time in training. For example, Kopstein and Roshal (48) found that prompting was especially efficient early in training.
(2) Trainee's past performance. One might never prompt a response the trainee got right on a previous trial. Thus the proportion of prompts might be diminished as he gets more items correct.
(3) Properties of responses required. One might prompt according to something inherent in the subject matter, such as the number of items which the average person can remember, or the logical units of subject matter.
(4) Speed of response. One might give a prompt only if the trainee does not respond correctly within a second or two. This would limit the amount of wild guessing, assuming that he could give the right answer quickly if he could think of it at all.
(5) Trainee's request for prompt. One might reduce wild guessing by instructing the trainee to ask for a prompt if he doesn't think of the answer right away.
c. Completeness of prompts.
(1) Cue (partial). Any hint of the correct answer is called a cue. For example, one might give two or three letters of a response word, or a word which rhymes with the correct word.
(2) Prompt (complete). Telling the trainee exactly what to do, before he does it, is called a prompt.

4. **Supplementary Knowledge of Results (KR).** This means giving a student information about the adequacy of his performance, beyond what is intrinsic to the task.

    a. Size of response unit.

        (1) KR after each step.

        (2) KR after end result. Here it is also important whether the knowledge can be traced back to a particular response.

            (a) General KR. This is information on performance not relatable to particular responses, so that the student may know how well he did generally, but cannot determine which responses were adequate.

            (b) KR specific to a particular step. Although the information is delayed till the end of a sequence, it has such a form that it can be related to the adequacy of specific responses.

    b. Form of KR.

        (1) Providing comparison. The trainee is shown the correct response, with which he can compare his own (e.g., in a spelling test, being shown the correct spelling). The effectiveness of this method depends on his remembering his response, and his discrimination between the correct response and an error.

        (2) Giving assessment. The trainee is told whether or not his response is adequate, and in a way that does not require him to compare his own response with a correct answer.

5. **Manipulating Incentives.** Incentives are often problems in training because the normal rewards of the job are absent, unless special provision is made. Student awareness of improving job performance is a somewhat indirect incentive, but it is sometimes effective.

    a. Adding incentives.

        (1) Are incentives dependent on task success, or what?

        (2) What schedule of reward is followed?

    b. Emphasizing existing incentives. This may be done whether or not extra incentives are awarded.

B. **Diagnosis of the Behavioral Process.** This kind of training analysis involves diagnosing deficiencies, either in a student's performance or in the performances of similar learners, and reckoning the general kinds of adjustments in training that might induce the desired behavior. Although such diagnoses may have implications for operational training variables, they are not the same as the training operations discussed in the preceding section. The essential issue here is the behavioral mechanism involved, rather than the alterations in situational variables. Athletic coaches commonly use such process diagnosis for perfecting motor skills. The following list is not exhaustive.

1. **Promoting Intrinsic KR.** Promoting the use of the knowledge of results that is intrinsic to the task.

    a. Clarifying goal state. This method assumes that the trainee can see in his task situation the successive approximations to the goal state, and can therefore adjust his actions accordingly.

    b. Calling attention to subgoal images. For example, in teaching someone to park a car, a driving instructor may call special attention to the position of the car when it is halfway in, just as the direction of turn is reversed. The description of such a subgoal situation may be given during task performance, or sometimes the subgoal may be described outside the training situation, especially when time pressures do not permit extra discussion during task performance.

    c. Providing supplementary KR. This is additional feedback, provided to reduce disruption from delay of intrinsic feedback; for example, a bowling teacher might tell a trainee that his delivery was good, without waiting for the ball to hit the pins.

2. **Fostering Conception of Underlying Process.** The principle of the apparatus is explained, or an analogy is drawn, to clarify the effects of responses. For example, in flying an aircraft, "to maintain balanced flight with the rudder pedals, look at the instrument panel, and imagine the little ball is a grape, being squeezed back and forth between your feet." This differs from any of the methods described above, in that the process to be conceived is not apparent in the cues in the task; so the process conception acts as a mediating event, rather than a subgoal cue. Process conception may be considered as stimulus reinterpretation.

3. **Establishing a More Effective Response Set.** Establishing a response set that is likely to produce more effective feedback.

a. Promoting movement consistency for better feedback. Instruct the trainee in form, to eliminate all but main motion. Thus the sources of variation in movement are reduced to a minimum, so that he can attribute error to only a few sources.

b. Establishing response set which permits sensing of feedback. Establish a set to respond in a way which will allow the trainee to discriminate the needed feedback, and indicate to him his need for that kind of feedback. For example, in an aircraft, "hold the stick loosely, so that you can feel small differences in pressure, and attend to the pressures."

4. Inducing Set for Appropriate Response Pattern. Inducing a response set for an appropriate pattern of motions or pressures to achieve task objectives.

a. Physically guiding responses. The coach forces the student's hand to follow the correct pattern of movement.

b. Describing desired modifications of responses. The trainee is told how to modify his responses; for example, "follow through more on that swing."

c. Inducing set to avoid common mistakes. A response set is established to avoid commonly made mistakes, or common kinds of inadequate performance. For example, in water skiing, "lean back as you start, and don't let the boat pull you off balance forward as it pulls you out of the water. Or, if there is a lag in some tracking control system, you may avoid over-controlling if you consciously delay any response somewhat."

d. Instructing on grip or stance.

5. Inducing Cue Sensitivity. Inducing sensitivity to a cue, to establish a timing cue or a significative cue.

a. Signaling, during task performance, the moment for a response.

b. Describing situation which is to trigger the action.

6. Encouraging Anticipation of the Response (Reading Ahead). The student is encouraged to read ahead more, in order to organize larger units of responses. For example, in reading music, the student is likely to be directed to look ahead of where he is playing. Doing so involves changing his perceptual responses and increasing his use of short-term memory. When he shifts to longer span in short-term memory, he presumably reorganizes the material for greater efficiency.

Chapter 4

TASK TAXONOMY (RESPONSE PROCESSES)

MAJOR CATEGORIES

In the taxonomy as it now stands, there are four major categories, as follows:

Task Category	Common Reference Terms, and Examples
Reactive Tasks	
Adjustive	Tracking or adjusting: adjusting a knob, steering a car, stick control in flying a plane, steering a bicycle.
Selection from a set of responses	Typing, sight reading in playing a piano.
Developmental Tasks	
Procedural	Procedures: aircraft flight procedures, procedure for assembling an M1 rifle, starting a tank.
Skilled performance	Skilled act: batting a ball, laying a single brick, performing a hand stand, vaulting over an obstacle.

Reactive tasks are those in which the character of the task is homogeneous over time. The term reactive was chosen to emphasize the fact that the appropriate response is defined by a cue that is immediately relevant to the environment. Within the reactive category, a distinction is made between the adjustive class, in which the trainee is to effect an alignment or a nulling of a stimulus dimension, and the selection from a set of responses class, in which he is to respond to a specifying cue in the task situation.

Developmental tasks, on the other hand, involve changing task demands (the trainee is required to do several different things in sequence) during any particular instance of performing the task. The term developmental refers to the fact that each performance develops over several phases, having a beginning, a middle, and an end. Within the developmental category, a distinction is made between the procedural class, in which the trainee is to perform a fixed sequence of steps, and the skilled performance class, in which success is a matter of fine skill or technique.

Performance on a procedural task is judged on qualitative standards, and generally, performance on each single step is already well learned at the start of practice. Knowing procedures is knowing what to do, and when. Skilled performance tasks involve the quantitative aspects of performance, or how well the task is done. However, the lack of the necessary degree of skill sometimes may have qualitative consequences (as in football when a pass goes wild and is intercepted).

Procedural tasks and skilled performance tasks often occur as different aspects of the same performance, and it is sometimes difficult to determine whether a particular error is attributable to one aspect or the other. For example, a student pilot might be going into a normal climb (as described in the Appendix, item 4), and have difficulty in holding the speed at 100 knots. If the instructor questioned him, "What speed are you trying to hold?" and the student answered "100 knots," the instructor would conclude he knew the procedural step but lacked the necessary degree of skill in holding nose attitude.

In view of the ambiguities, one might be tempted to discard the distinction between procedures and skilled performance, except that it is widely noted in practice, and probably for good reason. The distinction, in practice, seems one of process; procedures are a matter of correct language behavior in the appropriate situation. The distinction is useful presumably because the procedural aspects can be practiced separately as a subtask with only gross simulation, and because use of language permits rather straightforward training methods (telling the student what to do).

THE NATURE OF THE FOUR MAJOR CATEGORIES

In order to understand how training strategies for the four major categories differ, one should have a clear idea of the general basis of the distinctions among them. Although the following discussion may lack rigor it is perhaps better to give a general impression of the basis of task categories, than to leave the definitions as pure abstractions.

The most primitive category is developmental—skilled performance. Such tasks are of the general kind that changes in composition as time passes, and in which detailed technique is important for achieving task objectives. Most individual athletic feats, and most performance of trained animals, fall in this category.

With the advent of language and machines, developmental—procedural tasks became an important category. Language makes task control by categorical means possible by describing what is to be done, and the whole process of language performance may be conducted somewhat independently from other aspects of performance. That is, one may talk his way through the actions required in a procedure without overt practice in the task environment (even though such verbal practice may not be as efficient). The advent of machines also contributes to the categorical nature of some tasks, for it is easy to see when a person stops manipulating one part and begins working with the next part, and machines tend to be analyzable into subsystems and parts.

The machine has also created another kind of task, reactive—adjustive. Such tasks involve an input in some cue dimension which is to be nullified by responses. The homogeneous kind of input can readily be created in a machine that has rather static properties, and it is often desirable for a person to keep some aspect of the machine approximately in an optimal state by nullifying disturbances from the environment. Some developmental—skilled performances, such as holding one's balance in walking, might be considered as reactive—adjustive tasks. However, the dynamics of balance goes through cycles with each step instead of being homogeneous, and the total human frame does not have the rigidity of a single lever; hence the task analysis tends to be considerably more complex than the analyses which have proven so profitable in the tracking skills. The purpose of classifying a task as tracking (i.e., reactive—adjustive) is (a) to be able to apply certain training strategies appropriate for

simple skills which are homogeneous over time, and (b) to obviate the need for certain other strategies designed to clarify for the trainee the changes in task dynamics in performing developmental tasks.

Finally, many so-called motor tasks are in reality information processing tasks which seem to keep the person busy on the effector side. These have been called reactive—selection from a set of responses. These are likely to be called motor tasks when there is a directly corresponding symbolic cue (specifying stimulus) for each response in the immediate physical environment; thus type-writing is more likely to be called a motor skill than is operating a calculator.

Several aspects of such tasks have implications for training strategies: (a) the symbolic nature of the cues; (b) the time between perceiving the cue and the time that the response is required (anticipatory interval); (c) the fact that the devices that support such tasks (e.g., typewriters) have generally been designed to make each individual physical response as easy as possible, and therefore a fairly small part of the task burden for the subject.

"MIXED" TASKS

Some tasks do not seem to fall clearly into one or another of the categories, although this seems to happen much less often than might be expected. Of course, a total job or job activity is apt to lead to the problem of "conglomerate learning requirements" as discussed previously. but when the job or activity is analyzed into apparently homogeneous phases and functions the problem is much reduced.

The general rule is to classify a task as developmental—skilled performance (the most primitive category) unless there are reasons for doing otherwise. A very common training strategy for this sort of task is to analyze out the procedural aspects, and teach them by the generally simpler methods appropriate to procedural tasks; that is, by telling the student what to do, in what sequence, as if the task were a series of distinct steps rather than a continuous process. As people grow older, however, they have an increasingly large repertoire of individual task steps mastered, which can be assembled into new chains by procedural learning.

When tasks appear homogeneous during their performance, they are in the reactive categories. It is their stability over time that permits relatively simple methods of training. It may seem paradoxical to call the analysis and description of tracking tasks "simple" (such terms as "double integral," "lag," "damping," "quickened," "aided" tracking control represent complex concepts), but the corresponding analyses of developmental—skilled performance tasks are so complicated by comparison as to be impractical. The "reactive choice" tasks are products of a special environment and of machines designed for a very special purpose. If each physical response itself were difficult, especially poor task design and tediousness of learning would be reflected. In typing, for instance, there might be some need to work on individual strokes, which would be treating each stroke as a developmental—skilled performance task; the start of the motion toward the intended key, the correct curve into the downstroke, and so forth, all consolidated into a ballistic motion. But such part tasks are usually simple, and seldom require detailed attention.

SUBCLASSES OF TASKS

The four major categories are defined in terms of distinctions derived from various discussions of motor skills. Not surprisingly, some categories resemble

commonly used concepts. More notable is the fact that within each of the major categories a different set of characteristics is used commonly to describe tasks, because so many of the terms used in describing tasks actually are more specific statements of major category characteristics. For example, a hunter might be required to "hold a lead" in aiming at a bird in flight, and this partial task description implies the characteri itics of the more general category, reactive—adjustive tasks. Most empirical comparisons among tasks are comparisons within one of the major categories.

Because people tend to note the more specific task characteristics, they will be listed for each major category as a means of clarifying what is implicit in the major category. The more specific task characteristics are likely to be useful in revealing the underlying learning process, in providing a logical basis for altering the process, and in indicating the training strategies commonly used for a particular kind of task.

In the following paragraphs, the four fundamental categories are defined more rigorously and subdistinctions are noted, usually in the form of questions. The implications of these questions cover much of the design of training (much too broad a topic to be considered here), but they will be considered in a limited way in discussing the applicability of training strategies to various kinds of tasks.

A. Reactive—Adjustive. In tasks of this type there is an underlying continuum, usually spatial, for the stimulus and response dimensions, and a response directly alters the stimulus dimension. The task is to reduce a discrepancy in the stimulus dimension to zero. (Thus, this discrepancy is a "significative cue," as defined previously.) The magnitude of the stimulus dimension which was not canceled by a particular response remains as a stimulus input for later responses.

1. Stimulus Input. Is there only one stimulus change or input, or is the input repeatedly or continuously adjusted?

a. Single input. This is typically an alignment task, in which only the trainee's responses change the extent of misalignment during task performance. Adjusting a radio knob is one example of a single input adjustive task. Such skills, if they are demanding, are generally stringently timed.

b. Repetitive or continuous input. This category includes the common tracking tasks. The characteristics of the input function, over time, will affect the choice of the optimal control system (50.

2. Anticipation Interval. The interval between the instant a cue is received and the time a response is to be made is the anticipation interval.

a. Anticipation. Can the student see ahead? If so, how far? For example, in driving a car, a person sees the road ahead before he must respond.

b. Autocorrelation. Is there a regularity in the stimulus pattern over time which may serve as a basis for anticipating the required movements? This is the issue Fitts (5) called coherence; often it may be measured by autocorrelation.

3. Feedback Degradation. What degradation of feedback is present, if any?

a. Lag. Is there a lag in feedback, and is the lag greater than reaction time? This factor tends to accentuate the vagueness of a reference indicator, because one has less chance to correct misimpressions. Reaction time is considered a critical division, because when lag exceeds reaction time, the trainee can make a second response before he sees the effects of the first. The difficulties of flying a helicopter result largely from lag, and Fitts (5) reports that even lag of less than one second can be extremely disruptive.

b. Clarity of reference marks. The clarity of the feedback function can affect accuracy; for instance, when aiming a rifle it is easier to shoot directly at something than to estimate a lead. The lack of clarity may be in the target, or frame of reference (i.e., reticle), or both, since both target and frame of reference are necessary for the student to infer the error feedback. A recent study used instances in which clear reference marks facilitated tracking performance to explain and exemplify augmented feedback (51).

c. Feedback function. What is the mathematical function relating control movement (or change of force on a control) to the change in magnitude of the feedback signal? This

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mathematical relationship is a fundamental characteristic noted for tracking tasks. Also, this characteristic implies that it is a reactive—adjustive task, because it is reactive tasks that have a homogeneity of function over time and adjustive tasks that have a feedback signal on a stimulus continuum. Also, if the mathematical relationship can be analyzed into simpler subfunctions (as a double integral tracking task can be analyzed into the first integration and the second integration), then one may also note whether each corresponding subtask has a separate feedback signal in the environment.

4. Criterion Emphasis. Is one particular point of the criterion given special weight, such as speed, accuracy, c a particular performance interval? If so, the trainee may be able to selectively attend to the critical matters; similarly, training may concentrate practice on the critical processes. (Such selective attention is likely to be trained by stimulus predifferentiation operations, as discussed in Chapter 3.)

a. Speed and accuracy. Which is more crucial, speed or accuracy? Although most tasks set minimum standards of speed and accuracy, they may place special importance upon one of the two.

b. Performance interval. What time intervals are important? Sometimes only certain of these count (e.g., aiming, in which only time of firing is the critical moment). Other tasks, such as driving a car, require continuous tracking and attention.

And if only certain intervals count, can the trainee use his discretion to initiate the action (as in aiming), or can he anticipate when his cue will appear (as a driver can anticipate when his car will reach an intersection for turning left)?

c. Subtask emphasis. When there are several concurrent subtasks, are some more important than others? The trainee might be able to learn signal hierarchy, to establish response priorities.

B. Reactive—Selection From a Set of Alternatives. The subject makes responses, chosen from a set of responses appropriate to that general task context, each response is called out by a specifying (or prompting) stimulus from the environment (e.g., typing, playing piano from music). There is to be a symbol for each response choice; in cases in which the subject must generate the symbols as he goes (e.g., typing while composing prose), the symbol generation is to be considered another kind of activity. The following are dimensions which define subcategories.

1. Anticipation Interval. During the anticipation interval (the time between receiving the symbol and making the corresponding response), the processes which may occur are conditioned by certain task characteristics.

a. Restriction of interval. Is there a practical restriction upon the number of specifying stimuli that the student may store in memory before responding? In typing, one can read ahead as far as he wishes in order to organize the material before typing; or in taking shorthand, one may lag behind the person speaking, as long as no material is forgotten. But imagine a typewriting situation in which each letter must be typed before the next one will appear; such a peculiar typewriting task would severely limit the learner's organization of the material.

b. Symbol hierarchies. Are there hierarchies of organization of the symbols, with corresponding statistical dependencies among the symbols, in the frequency with which the symbols occur? In typing, such hierarchical arrangements are the basis of word and phrase habits that augment speed. It seems likely that the mediating processes that occur during the anticipation interval are organized according to the hierarchies.

2. Pacing. Is the task self-paced, and is the rate of production the criterion of skill (assuming a certain minimum standard of accuracy)? (Typing is self-paced, but shorthand is not.) When a task is self-paced, the student has an opportunity to attempt various rates of performance. When the specifying stimuli are task-paced, he can control rate only indirectly, by choosing the material for practice. As the input rate increases, he has the additional burden of attending to new specifying stimuli while he is responding to the previous cues, which may be somewhat unrelated to the new ones.

3. Character of the Response Units. The quality of each response unit may involve special learning difficulties, beyond organizing and selecting the responses. In a very difficult practical skill, perhaps each individual response may need to be learned as a subtask (of the developmental—skilled performance variety, as discussed later); and then the choosing of the responses may need to be learned as a reactive—selection task.

a. Spatial location. Are there different spatial locations for the responses of the set, as in typing? Or is there no spatial response organization, as in taking shorth~~ ' with pencil and pad? If responses are organized spatially, their positions may be substitute(for longer, complex, or subtle movements.

b. Time for each response. Is the performance of each response taking longer than the trainee's reaction time? When there is insufficient time for a feedback loop to occur. the responses are apt to be "ballistic" responses. Responses of longer duration are likely to be found in developmental skills, as discussed later, because the trainee may be making a series of partial responses during the interval.

C. Developmental—Procedural. This kind of task involves performing a series of steps in a fixed order. The performance criterion requires that the st.ps be performed, but does not specify how well or skillfully each step is performed. An example is flight procedures in an aircraft.

1. Task Direction (Specifying Stimulus). Is there a specifying stimulus for each step in the criterion situation, or must the steps be performed from memory? Instances in which the specifying stimuli are always present are an aircraft takeoff checklist (mounted on the instrument panel), and the aircraft production assembly technique in which the steps of the assembly are pictured in a series of projected slides, with accompanying audio directions. Jobs that have such job aids, or specifying stimuli, tend to be quite easy unless they are very severely paced, or unless extreme accuracy is required, or unless changes in the job are frequent. Often, such job aids can be provided for a task to simplify it. If a job is very difficult even in the presence of job aids, the indication is that the individual steps were difficult, and that the learning of each step is generally a matter of performance skill, as defined later.

2. Timing of the Steps. Is the task self-paced or task-paced? If it is task-paced, can the task pace be changed for training purposes? Slowing down pace is a way of making practice easier; also, one may want to speed up practice of certain task segments, if the trainee is not busy. The source of pacing for the task will reflect the importance of speed, and the feasibility of slower practice.

3. Hierarchies. Are there hierarchies for organizing the response units? Such hierarchies tend to make the steps more memorable.

4. Alternative (Branching) Procedures. Are there situations in which the task requires alternative procedures (e.g., emergency procedures)? Such alternatives sometimes may be practiced separately, especially when they are seldom used.

D. Developmental--Skilled Performance: This type of task is concerned with the degree of skill required to control a process that evolves through distinct different phases on any particular instance of task performance. The task functions and criteria vary in different phases. For instance, in laying a single brick, the mason must scoop up the desired amount of mortar with an efficient motion, spread the mortar evenly with a quick motion of the trowel, and place the brick to maintain a fairly even and vertical wall (emphasis to indicate matters of degree of skill). Although this performance also has procedural aspects, they are so simple as to be trivial: scoop mortar and place it on last row, set brick on mortar. Other examples of this kind of task are pitching a ball, or shaping a piece of pottery.

The tasks in this category are especially likely to involve some sort of task pacing (or motor coordination, or timing) if they are difficult, because many other sources of difficulty are ruled out by the task definition. Such tasks do not require remembering what to do (procedural tasks), nor is there a heavy burden of symbolic activity involved in reacting to a rapid series of specifying stimuli (e.g., typing).

Developmental—skilled performance tasks are generally described by reference to the product produced or the process controlled, of which there are r great variety. Often the nature of the material or process being controlled has special relevance for training on this kind of task.

The kind of response chaining involved in tasks of this category may be revealed in the effect of artificial feedback lag. Since the process is an evolving one, the stimulus produced by one response is likely to be the triggering stimulus for the next response. If the feedback (stimulus produced by a response) is delayed artificially, then there will be a strong tendency

to repeat responses. This appears to be what happens when speech sounds are delayed for a fraction of a second (by electronic means), then transmitted to the speaker; he stutters uncontrollably. Normally, a person speaks each word under two simultaneous cue conditions: (a) He has just made motor responses to the previous word or syllable, and (b) he hears the previous word or syllable. When these two cues are separated, either has a tendency to elicit the word. This kind of event differs qualitatively from what happens to tracking under conditions of delayed feedback. In tracking, the error feedback, if it is delayed, merely results in another comparable response, so that the two comparable responses can summate, and the result is overcontrolling; the speech sounds cannot summate, even if the feedback is delayed electronically, because they differ qualitatively. However, a common consequence is a new, hybrid response.

Chapter 5

RELEVANCE OF TASK CATEGORIES IN
SELECTING TRAINING STRATEGIES

The purpose of this task taxonomy is to sort tasks so that a different set of training strategies is applicable to each category of task. This section is intended to demonstrate, in a limited way, such an interaction between the various training strategies and the kinds of perceptual-motor tasks.

In some instances, particular training strategies will be logically inapplicable because of the definitions involved. In other instances, applying a training strategy to one kind of task would be a very different matter from using it with another kind of task.

A list of the gross categories of tasks and some finer distinctions is shown in Table 2, these are related to major varieties of strategies. In the table the numbers at points of interaction refer to the numbered text paragraphs in which the interactions are discussed.

(1) Stimulus predifferentiation methods may apply to reactive—adjustive responses when the cue function is unclear, or when there are no reference marks. In such cases, the function of stimulus predifferentiation is to clarify the feedback quantity for the trainee.

(2) In reactive—choice tasks, the major cue in the task environment—the specifying stimulus—is a meaningful, symbolic cu   so it need not be further discriminated. Thus there generally is no purpose in stimulus predifferentiation methods for tasks of this kind. But if the response choices are spatially defined, one might try a backward association drill (Recall of Differences method of stimulus predifferentiation) by having the trainee give the symbolic equivalent of each response position. Also, spatial configuration of response choices would permit one to give a pattern of spatial cues corresponding to the required responses. For example, in typing one might show a keyboard picture, with a light behind each key, and show the sequence and rhythm of responses in typing some common words, in an attempt to induce an image (developmental image) which might serve to mediate correct responses.

(3) In learning developmental—procedural tasks, the main feature is to remember what to do, not to perform with high skill. The stimulus problems are those of remembering gross distinctions, rather than of sharpening fine distinctions. Thus terminology drill might be appropriate, or the demonstration of tolerance limits, or recall of differences. Yet these would probably be a matter of associating words with various cue states. The gradual narrowing of a discrimination would be more likely to be involved in other kinds of learning—those that involve quantitative rather than qualitative performance requirements.

(4) The stimulus predifferentiation strategies are especially suitable for a developmental—skilled performance task, which is not homogeneous in cue function; one might have to learn to discriminate many significative cues or triggering cues. The phrase "heterogeneous cue functions" implies that there are more cues to learn. Also, the cues might require quantitative', ' ie discrimination,

Table 2

Interactions of Task Categories With Training Strategies[a]

Training Strategy	Reactive		Developmental	
	Adjustive	Choice	Procedural	Skilled Performance
A. Operational Conditions of Practice				
1. Representation of task environment				
a. Unmodified				
b. Modified				
(1) Stimulus predifferentiation	(1)	(2)	(3)	(4)
(2) Response practice under progressively more difficult conditions	(5)	(6)	(7)	(8)
2. Analysis into subtasks	. . . . (9)			
3. Performance requirements information	(13)	(12)	(10)	(11)
4. Supplementary knowledge of results	. . . . (14)			
5. Incentive manipulations				
B. Progress Diagnosis				
1. Utilizing knowledge of results				
a. Clarify goal state	. . . . (15)			
b. Call attention to subgoals	. . . . (16)			
c. Supplementary (early) knowledge	. . . . (17)			
2. Process conception	. . . . (18)			
3. Response set for effective feedback				
a. Movement consistency	. . . . (19)			
b. Avoid responses which mask feedback				
4. Overt response patterns	. . . . (20)			
5. Sensitivity to cue indicating moment for response	. . . . (21)			
6. Response anticipation	. . . . (22)			

[a] Each number in the table refers to the text paragraph in which that particular interaction is discussed; e.g., Stimulus Predifferentiation, as applied to reactive—adjustive tasks, is discussed in paragraph 1. When a number covers all four task categories, that training strategy is discussed for all tasks in the paragraph indicated; e.g., Analysis into Subtasks is discussed in paragraph 9, for all four task categories.

as well as recognition of gross cue states; the progressive narrowing of discrimination strategy may be especially appropriate.

(5) In reactive—adjustive tasks for which there is repetitive input, the performance is essentially task-paced, and may be slowed to make it easier. Such slowing of the task pace is altogether different from reinforcement of slower responses, which may be employed in self-paced tasks, such as adjustive tasks for which there is a single input. The force and amplitude requirements might be modified at first if the trainee does not meet task standards. However, there generally would be no basis for easier standards of form, since performance is usually judged on some such unidimensional basis as error or time-on-target scores, rather than on configuration of response.

(6) When reactive—choice tasks are self-paced, one may require less speed at first, but there is likely to be little advantage in slowing performance if the required motions approach the trainee's reaction time, because the whole nature of responses changes. When reactive—choice tasks have a spatial arrangement of responses, the form of response is a qualitative matter, not readily modifiable. When there is no spatial arrangement of the responses, as in sending Morse

code, there might be some leniency in form; but if the response intervals are short, the result is apt to be a different pattern of chaining responses.

(7) Because developmental—procedural tasks are matters of remembering the response, rather than of performing skillfully, they provide an ideal situation for modifying response demands in speed, force or amplitude, or form. Also, the physical situation for such procedural tasks generally allows for modifying both the time and the form of response.

(8) In developmental—skilled performance tasks, a very common practice is to change requirements of form of response and amplitude or force of response. However, often the timing cannot be ch   1, since kinetic energy is a significant aspect of the movement involved.

(9) The analysis of a task into subtasks may involve any of the task categories. The analysis into successive tasks (or phases of tasks) is trivial as it pertains to training methods, and is merely a matter of convenience.

Also, the analysis of tasks into concurrent, independent subtasks is relatively trivial with respect to analyzing into subtasks and training for them. The training of the total task concerns only the timesharing of activities.

The analysis into dependent subtasks is especially likely to be involved in reactive—adjustive tasks and developmental—skilled performance skill tasks. In reactive—adjustive tasks, the cue function (significative cue) at any moment is partly a result of error on previous responses, as well as a function of fresh input into the task. Also, the new input may be affected at any moment by past error (depending on the mathematical control function involved). Such dependence of cue functions upon past performance is involved in many kinds of subtask relations.

Many aspects of developmental—skilled performance tasks are similarly interdependent over time. Such tasks are often much like the reactive—adjustive tasks, except that the cue functions are less homogeneous over time. The advent of machines makes homogeneous cue functions rather common, and thus creates numerous tasks of the reactive—adjustive sort. But many of the same processes are involved in developmental—skilled performance tasks, although it may be more difficult to analyze such tasks into stable mathematical functions.

The reactive—choice tasks generally do not have such dependence among their subtasks, since they generally do not involve dependence of the cue function upon past performance. Also, developmental—procedural tasks involve the qualitative aspects of performance, and a generally invariant sequence (since they can be learned as a chain), so the appropriate next step does not depend upon preceding performance.

(10) The presentation of task requirements information during task performance is almost exclusively a technique for teaching procedural tasks (developmental—procedural tasks). Such tasks almost always involve remembering the steps beyond the span of immediate memory (unless there is a job aid, such as a check list).

(11) To some degree, one might also use prompting and related strategies in teaching developmental—skilled performance tasks, since these may involve long heterogeneous chains of responses. However, in such cases, the prompted practice amounts to extracting the procedural aspects and practicing them as a procedural subtask. For instance, when a baseball player is learning to slide properly into a base, he at first is probably coached through the motions one by one. In this way procedural aspects become a subtask of the developmental—procedural variety.

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(12) Reactive—choice tasks would probably not be improved by manipulation of prompts, for such tasks have a specifying stimulus as an element of the task itself (assuming that a prompt is defined as a specifying stimulus). The special prompt would be exactly redundant with the specifying stimulus. In typing, for example, prompting would be an extra copy of the thing to be typed.

Yet some form of nonsymbolic indication of the required action might be beneficial. In typing, for example, one might flash a light on each key to be typed, to promote letter-key association. But the fact that the guidance is non-symbolic makes it a different kind of training strategy.

(13) Reactive—adjustive tasks have homogeneous input and rather few task elements, so that it is likely that a student can remember what to do when he is to perform the task. The difficulty is how to do the task, not so much what to do. Thus an ordinary symbolic prompt (i.e., specifying stimulus) is apt to be of little value.

Yet some forms of guidance cues may be beneficial during training. Perhaps the future position might be indicated somehow on the display, if lag is a problem. Or perhaps reference marks might be sharply defined early in training, if the trainees seem not to have a clear idea of the task. Or the output of some subtask might be superimposed on the display, if that output is not normally displayed to trainees.

(14) The size of the response unit indicated in knowledge of results is an issue that is especially applicable to developmental tasks. Reactive tasks are fairly homogeneous over time, and do not have an end result and identifiable steps to that goal; it is therefore unlikely that after an interval of practice on a reactive task, any knowledge of results could be related effectively to a particular moment of performance.

The forms of knowledge of results which were distinguished could be applied to any of the task categories, although the methods of application might differ.

(15) The achievement of a goal state, in the sense implied here, is a matter of development by a whole series of responses; hence, describing such a goal state would be of potential benefit only in developmental tasks. With developmental—procedural tasks, the goal state might serve to organize or make more vivid the particular responses, insofar as it is possible to relate the individual responses directly to the goal state. But in developmental—skilled performance tasks, the image of the goal state is more than a mere aid to memory, since it may indicate directly the movement needed (from the present position) to achieve satisfactory performance. In such tasks, the goal image plays a role very similar to the reference marks, or reference field, in reactive—adjustive tasks (e.g., the reticle in telescopic gun sights).

Performance on reactive—choice tasks may be aided by goal images in a different sense of the word. Instead of indicating the next response required, the goal image may be a restructuring of the responses into a hierarchical arrangement. The result would be the same series of responses, but the learner would be processing the information differently. In typing, for example, instructors may talk about word habits and phrase habits as increasingly efficient ways of processing information, but with no qualitative difference in the sequences typed. Although such distinctions in a trainee's covert processes may be in doubt, the issue here is the opportunity for such processes, as contrasted with the further possibility in developmental—skilled performance tasks, that the goal image will help him decide what the next response should be.

(16) Calling attention to subgoals is not likely to be used with reactive tasks because such tasks are homogeneous over time and are therefore not divided into significant phases of performance, or subgoals.

(17) The effect of supplementary knowledge of results, in the sense used here, is restricted to the information the trainee is given by the instructor concerning whether he performed correctly, or what he should have done; it does not include general incentive effects, such as total score (without indicating errors). The effects at issue thus concern the delay between a specific performance and the information about its correctness.

Early knowledge of results would be more likely to be used with developmental tasks, in which a whole sequence of responses leads to a goal, and for which the relevance of individual responses may not be known until the goal is reached or missed. In reactive—adjustive tasks, delay or lag in feedback may be bridged by some more rapid means of indicating amount of error; yet one is working only with a short interval, and supplementary feedback information from the instructor may have cue value which is not present on the job, and which may therefore become a vehicle for negative transfer of training.

In reactive—choice tasks, the possible deficiency in knowledge of results is generally not a deficiency in goal image, for the desired responses are given in the environment as specifying stimuli.

In developmental—procedural tasks, the early knowledge of results is a qualitative matter; therefore verbal descriptions are generally adequate. Also, if prompting is given, the knowledge of results would be redundant. With developmental—skilled performance tasks many more things are a matter of degree, and for this reason generally much more difficult to describe in words.

(18) The conception of the physical process in the task environment may serve various functions, depending on the task category. In reactive—adjustive tasks, it may be used to make the direction of correction seem natural, or it may be used to facilitate transfer of training if the student actually has learned a task that involves similar control dynamics.

With reactive—choice tasks, the mechanical process underlying the apparatus seldom relates to the performance of the task. Hence, knowing the mechanical process helps little; for example, there is no reason to suppose that one could play a piano better if he knew how a piano is made. Yet there may be a physical process that underlies the organization of responses and might be useful in establishing response hierarchies; for example, in playing a piano from music, knowing the principles of harmony may help to categorize chords, making them more meaningful.

With developmental—procedural tasks, the mechanical principles may make the particular acts seem less arbitrary, hence more memorable. But it is in developmental—skilled performance tasks that the process conception is often an aid, sometimes essential to effective performance. In such tasks, there is a change in status during performance, and the trainee must know what the process is and when the changes occur. For example, if a piece of equipment has a hidden catch which has several safety features, one needs to know something about the shape of the thing being manipulated. Or in tooling a piece of steel, one should know some of the properties of the particular kind of steel: hardness, ductility, brittleness, changes in properties with heat, and so forth. With such tooling (in contrast to the hidden catch example above) one's image of the properties of the material must be rather richly detailed in order to effectively control the details of such complex performance; such rich imagery is rather typical of arts and technologies which process raw materials.

(19) The training strategies dealing with response set for effective feedback are most apt to be pertinent for reactive—adjustive tasks or developmental—skilled performance tasks, because such categories generally are most concerned with details of response performance. These training strategies specifically refer to the intratask feedback process, which is a defining characteristic of reactive—adjustive tasks. The same general kinds of feedback are often present in developmental—skilled performance tasks, or at least in parts of them. But developmental—procedural tasks involve what the trainee is doing, rather than the details of how well he does it, and the feedback is likely to be general—that is, related to whether or not major goals were achieved. Reactive—choice tasks also are not likely to involve much kinesthetic feedback which might be used as cues for later motions, especially if the responses take no longer than the student's reaction time. The sources of motion are often restricted in reactive—choice tasks (e.g., typing), but the feedback is to be used to correct later instances of the same response, rather than to modify the next response in the series.

(20) Specific response guidance is generally used with reactive—adjustive tasks or developmental—skilled performance tasks. The developmental—procedural tasks, because they are the categorical aspects of performance, are more readily described in words, thus obviating the need for (a) the refinement of technique and (b) demonstration of the details of performance. For reactive—choice tasks, the specific response guidance might be used for the motion of each choice, but such physical motion is only a small part of the task process.

Establishing a response set to avoid common errors is a strategy that may be used on any kind of task, although the strategy does not always operate in the same way. In order to specify the task category to which this strategy is applicable, one would have to be more specific about the kind of common error tendency; for example, overcontrolling because of lag in controls is usually encountered only in reactive—adjustive tasks, or perhaps occasionally in developmental—skilled performance tasks.

(21) Such cue sensitivity is not likely to be encountered in reactive—choice tasks, because such tasks entail a specifying stimulus which generally precludes the need for additional cues to govern the timing of task performance. The situation sensitivity is also less likely to be encountered in reactive—adjustive tasks than in developmental tasks, for there is generally a homogeneous kind of cue, hence a correspondingly homogeneous kind of response process. Notable exceptions occur when particular moments are most critical, as in aiming a rifle at a moving target.

Indicating to the trainee, during performance, the moment when he should respond is more likely done when teaching skilled performance tasks than procedural tasks; in teaching procedural tasks, one would generally use the simpler method of describing the triggering cue.

(22) In the literal sense of reading ahead, one would need a specifying stimulus in the task environment. Hence, the strategy would apply only to reactive—choice tasks and to the few developmental—procedural tasks that use prompts in the job. But if a more liberal interpretation of reading ahead is used, the strategy would also apply to the reactive—adjustive tasks in which the track can be seen far in advance of present position.

In another sense, one might recommend planning ahead or thinking ahead in developmental tasks generally, but then the cues would be images or mental cues, not environmental cues. Hence, planning or thinking ahead would constitute a different mode of task performance, induced by a different kind of training strategy.

Chapter 6

CONCLUSIONS AND FURTHER DEVELOPMENT

The tentative task taxonomy presented in this report shows promise as an aid in designing training programs because several of its distinctions do appear (a) to determine which training techniques or strategies are applicable to various tasks, and (b) to describe differences in the training processes involved when the same general training strategy is applied to different kinds of tasks. Admittedly, many of the considerations need to be clarified considerably, and further development is needed.

FORMAL AND THEORETICAL DEVELOPMENT

The definitions for both the training strategies and the task categories should be refined, and subcategories specified. Such clarification would be facilitated by better description of the varied "covert" processes that underlie skilled performance. (Much relevant work appears in the experimental literature, but complete coverage of such work is not practicable here.) Although one could not expect exactly the same process from all tasks in a category, one should look for the ways in which category definitions limit the kinds of relevant processes taking place. As the taxonomy becomes more refined and detailed, it should be related formally to the training strategies, as was done in the last chapter but in much greater detail; this collation would be expected to yield many more formal restrictions in the applicability of various training strategies. Even when one cannot clearly establish whether a particular strategy is appropriate to a particular task, one should take notice of common reference points in the definitions.

Another line of development is to collect more task examples and training strategies. More people should think of more tasks, and various teachers and coaches who deal with motor skills could be queried systematically about their techniques. It seems reasonable to assume, tentatively, that the experienced teachers and coaches have a valid basis for their methods, so one should, at least as a beginning, make an effort to systematize their techniques. In interrelating these areas, one might use the connotative clustering technique described earlier.

As the taxonomy becomes further refined, it should be related formally to other taxonomies, such as the classification of educational objectives by Bloom and his associates (7).

EXPERIMENTATION

In conjunction with further formal refinement, empirical development will be appropriate. It will be of three basic types.

First, there should be sorting studies to determine whether people can sort common tasks reliably into categories. Reliable judgments are absolutely

necessary for a useful taxonomy, but it is well to remember that most classification attempts are at first very weak in this respect.

People might also be asked which training strategies they would use for particular task examples that fall clearly within the categories. If people could do this reliably, they would indicate limits on whether these strategies are applied within particular categories.

Another empirical development is to conduct experiments to determine the effectiveness of training strategies for various sorts of tasks. This may be the most direct test, but also the most demanding of research effort. It is hoped that research conceived within the framework of the taxonomic system may reveal differences in behavioral processes that are associated with the distinctions drawn. Presumably, one should be able to go to the experimental literature and find cases in which one task has been trained by different strategies, but theoretical experiments rarely follow such a research paradigm (as was noted in the first section).

The empirical evidence, for the most part, has yet to be gathered. There are so many distinctions and categories that one experimenter can do only a small fraction of the relevant research. It would be unrealistic to expect that the taxonomy would be "established" or "disproven" by one crucial experiment or by a short series of crucial experiments.

Often, one would attempt to experiment with tasks that border on other categories. Underwood (4, p. 49) refers to these as transition experiments, because they involve tasks whose classification is doubtful. If such experiments are to be instructive, however, one should have some idea of the kinds of processes in both categories, and of how training strategies are designed to affect the processes. In many cases, not enough is known to infer the processes until a considerable number of experiments have been performed.

Another kind of experimental approach is to try to determine the comparative effectiveness of various training strategies on tasks that fall clearly within a category; for example, learning to start an M48-A2 tank is clearly an example of a procedural skill. One might try various degrees and forms of guidance, perhaps examining in what respects a trainee could effectively adjust his own guidance by requesting needed information.

Several factors would indicate the nature of procedural learning—the importance of perceived hierarchy in organizing procedural steps, the effect of vividness of pictorial prompts, and the influence of physical realism during practice (32).

This kind of research would provide effective strategies, and perhaps enough knowledge about the underlying processes that comparability with other categories could be established. Such experiments have the added advantage of being applicable to current training practice, as well as providing a basis for a taxonomy.

Typing is a good example of a reactive—choice task. Experiments involving typing instruction might reveal the underlying processes. In teaching typing, straightforward prompts show little promise, because they simply duplicate the written text. But some special prompts might be useful, perhaps in the form of a keyboard display that flashes a light on the next key to be pressed, programed to correspond with a spoken text. Also, one might have a light behind each typewriter key and illuminate it when the corresponding key is struck on another typewriter at a remote station. If a stenographer typed messages at the remote station, another typist could perhaps learn to interpret the message from the sequence of flashing lights.

Tracking skills fall in the reactive—adjustive category. Perhaps there might be some way to use quickening during early training to adapt the task to

the trainee's ability level (53). Or perhaps there might be some way to indicate the optimal correction during training. Also, it might be significant to know the importance of multiple cues in feedback; for example, one might have a double integral tracking task, and study performance on a simple position display of the position function, compared with performance on a compound display which incorporates both rate and position information. The separate feedback signal for each subtask permits response according to the simpler mathematical relationships of the subtasks; frequently, it is these subtasks that are most naturally meaningful to the learner.

Within the developmental—skilled performance category the skill processes need to be further delineated, especially as they relate to various coaching techniques.

The areas for experiments are virtually unlimited, but perhaps one other area should be mentioned. Sometimes the amount of lag in feedback has seriously disruptive effects, such as in controlling a helicopter or in speaking with short delays before hearing the words. The amount of lag can be varied to see where disruptive effects occur for each skill.

PRACTICAL APPLICATION

Of course the final criterion of a taxonomy is usefulness, which takes into account not only consistency and empirical validity, but also the extent to which the classification goes beyond the trivial, and how readily it is understood. The taxonomy of Bloom and his associates (7) appears to have been useful for discussing learning processes in school, although testimonials are admittedly not the most rigorous of evidence. Perhaps others may find the present taxonomy useful, and their experience in applying the distinctions may well lead to modifications in the system.

The present taxonomy is designed to be useful for all the activities related to the practice of training, including determining what skills can be trained, choosing a training strategy likely to be effective, designing training environment and simulation, organizing past training and learning research, and conceiving future research. It is especially critical that the taxonomy should go beyond the obvious and the trivial, because it adds no new empirical evidence to the field; rather, it is merely an attempt at explication and organization of what is implicit in various current discussions of training. For such explication, it seemed necessary to go beyond the task classification, to the definition of training strategies. The training strategies themselves may help formalize what is done in training programs.

Practical application may also lead to further refinement of the classification by indicating which aspects are most useful, and by clarifying the shortcomings which appear. Practical application may also lead other researchers to use some of the features in their theoretic systems.

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Appendix

ANALYSIS OF SOME COMMON TASKS

1. <u>Learning to ride a bicycle</u> (a <u>reactive—adjustive</u> task)
   The first step is to analyze the task into three concurrent subtasks:

   ►Skill 1. Imagine the desired path of movement. (Turns should not be too sharp, as limited by the maximum angle of bank.)

   Skill 2. Regulate the desired angle of bank to produce the desired course, over time.

   Skill 3. Turn the handlebars to maintain balance at the desired angle of bank.

   This is a double integral tracking skill, and each integration is a separable cue in the stimulus environment (i.e., S can see directly his angle of bank, his course, and his path of movement). By separating these as skills, a simple mathematical relationship exists between response output and feedback; for example, one would turn the handlebars left to correct an imbalance to the left. A common error is to try to learn to steer left as a single integral system, by trying to turn the handlebars left. The constants of the equations change markedly with speed of the vehicle. The speed is controlled by S, but the difficulty at any particular speed is a matter of the physics of the task.

2. <u>Learning to drive a nail</u> (a <u>developmental—skilled performance</u> task)
   To drive a nail, not only must the hammer hit the head squarely, but there must be considerable force at impact. A novice is apt to ease the force on the hammer, or even to pull back, sometime before impact, greatly reducing the force at impact. Rather, he should imagine using the hammer to push the nail right into the board.
   This skill is representative of many skills in which follow-through is critical. The follow-through is a set to respond smoothly, continuously, over the time span involved. Although images may play a part in maintaining the response set, the follow-through is not a matter of reacting to maintain correspondence with an image, because any feedback signals would not have time to affect that instance of behavior, i.e., one could not sense hitting the nail and have time to adjust that particular stroke.
   Driving a nail is self-initiated, but there is an intrinsic rhythm which underlies the necessary coordination.

3. <u>Tying a square knot</u> (a <u>developmental—procedural</u> task)
   The critical thing is to remember where the rope should go, at various critical points. Although it is a "free" response, it has certain aspects of a choice among alternatives, because there are only a small number of possible alternatives at each critical point. Under normal conditions the manipulations are well within the motor skills of older children or adults; most people could

tie the square knot if one "talked them through," pointing where the rope was to go at each choice point. (But for very young children it might be considered a skilled movement task).

A point where people tend to make mistakes is half-way through; such an error will lead to a "granny" knot rather than a square knot.

4. Flight procedures: normal climb (a developmental—procedural task)

The following is a very much condensed description of the climb in a T-34B training aircraft.

Cue	Action
	(1) Raise nose.
	(2) Advance prop to full.
at 100 knots	(3) Full throttle
	(4) Maintain 100 knots with nose attitude.
	(5) Retrim.
	(6) "S" turns
at desired altitude . . .	(7) Lower nose.
	(8) Start retrimming.
120 knots	(9) Throttle back, 19" manifold pressure
	(10) rpm, 2000
	(11) Trim, and adjust power.

The Cue column tells what to be alert for when previous action is completed. The Cue events impose the task pacing, but there is no emphasis on speed. Although the actions referred to might not be smooth, or not even satisfactory, the cadet would be given credit for correct procedure if he didn't forget any step, or do the wrong thing, or incorrectly remember some gage valve; for example, his procedure is wrong if he said he thought they were to climb at 90 knots.

Generally, then, procedures include the qualitative aspects of the perform- ance, rather than smoothness, style, or dexterity. Also, one may be learning the procedure while the component acts are yet to be mastered, although there may be some ambiguity about whether an error is a result of not remembering the procedure, or about whether the execution was clumsy. In such cases of doubt, one might ask S what he was trying to do; this query assumes that pro- cedural responses are verbally mediated, or mediated by image, or by other processes accessible to verbal mediators.

5. Typing: ordinary prose (a reactive--selection from a set of alternatives task)

From the printed copy, or memorized prose, or composed prose, or dicta- tion at the typist's speed, select and press the appropriate keys. The typist can see ahead as far as he wishes, and performance is judged by rate of output, as long as accuracy is maintained. The copy may appear in any letter order, but almost always there are statistical regularities which may be used in organizing the responses.

There is a one-to-one correspondence between the copy and the responses; the characters in the copy (letters, numbers, punctuation) are the symbols which stand for the responses.

6. Learning to turn on the burners on a kitchen range (a developmental—
   procedural task, with this being an alternative (branching) procedure)
   The person must be able to turn on any of four burners, arranged in a rec-
tangle, by turning the corresponding control knob, without error (four knobs in
a line across the front of the range). Ranges differ widely in the pairing of
knobs and burners; this fact creates interference in shifting from one range to
another. Yet all arrangements seem to have the two knobs on the left paired
with the two burners on the left, and two burners on the right paired with the two
knobs on the right.

   Thus there are four common patterns of pairing burners and controls (e.g., left
front burner, control 2; left rear burner, control 1; right rear burner, control 4;
right front burner, control 3). There are many possible ways to train for a par-
ticular pairing, but straightforward rote association generally leads to inter-
ference among ranges, and rapid forgetting. An imagined pattern offers hope of
aiding memory. For instance, given the above pattern, one can image all the
burners as being in a large U or horseshoe, with the open end away. Then as the
U is bent open (in imagination), the burners line up with the controls, mediating
correct pairing (it is hoped). Or say that the burner-control pairing is reversed
on the left side. Then one may approach the range and step slightly to the left
of the range (or toward the refrigerator, or whatever is there). Then the burners
will line up across the perceptual field, left to right, in the same order as the
burners. The other possible pairings may be imagined as an upsidedown U, or
by stepping slightly to the right.

   This rather lengthy example illustrates that training techniques often involve
ingenuity, and that efficient strategies sometimes cannot be derived only from
the task to be trained. The relative efficiency of rote association vs. image
mediation is a function of many things: the clever choice of images, the inter-
fering habits or images, and perhaps the length of recall interval.

7. Operating trim tab controls in an aircraft (turning each control knob is a
   reactive—adjustive task with a single input; the order in which the knobs are
   turned may be considered a developmental—procedural task)
   Whenever the aircraft is to assume a new attitude, the pilot exerts force on
the primary controls (stick, and rudder pedals) to assume and maintain the new
attitude. If the new attitude is to be maintained for an appreciable interval, the
pilot should turn the three trim knobs until no pressure is needed on the primary
controls to hold the new attitude.

   It is important to view the three knobs as corresponding to the three rota-
tional degrees of freedom of the aircraft. This conception then mediates choos-
ing the correct knob for any constant control force; the pilot must then turn the
knob in the direction of his control force, in order to substitute turns of the
trim control for constant control pressure in that degree of freedom.

   It is customary to turn the knobs in the order, elevator, rudder, aileron, for
easiest adjustment.

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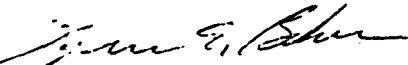### WASHINGTON, D.C. 20310

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1. This research is concerned with classifying job tasks with special reference to identifying the particular strategies applicable to training for various types of tasks. Two classification systems were developed--one for distinguishing various types of perceptual-motor tasks and one for training strategies pertaining to the task categories.

2. This classification system appears to be workable for determining training methods to be used for various types of tasks. Further research would develop the system further for effective, practical application.

3. This report should be of interest to those concerned with developing training programs, to those involved in motor skills learning research, and to those persons concerned with task taxonomy.

FOR THE CHIEF OF RESEARCH AND DEVELOPMENT:

1 Incl
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13. ABSTRACT

A system for classifying perceptual-motor tasks was devised for the purpose of distinguishing the kinds of training strategy appropriate for each task. A rationale is presented and various task elements are delineated in terms of cue functions, image or mediational functions, and movement tendency. The defined task elements were used in constructing two classifications: one of training strategies, and one of tasks. The classification of training strategies deals with the operational conditions of practice and the diagnosis of the underlying behavioral process. The task classification has four main divisions: reactive--adjustive (e.g., steering a car); reactive--selection from a set of responses (e.g., typing); developmental--procedural (e.g., starting a car); and developmental--skilled performance (e.g., batting a ball). Task sub-classes have been distinguished. Finally, the kinds of training strategies are related to the classes of tasks, as preliminary investigation of how well the task classification accomplished its purpose.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Education						
Information Processing						
Job Analysis						
Learning						
Perceptual-Motor Skill						
Task Classification						
Teaching Aids						
Teaching Methods						
Training						
Training Strategy						